DOCUMENT RESUME

ED 281 741 SE 047 935

AUTHOR Tobin, Kenneth
TITLE Exemplary Practice in Science Classrooms.
PUB DATE [87]
NOTE 18p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Case Studies; *Elementary School Science; Elementary Secondary Education; Foreign Countries; Science Education; *Science Instruction; *Science Teachers; *Secondary School Science; *Teacher Characteristics; *Teacher Effectiveness; *Teaching Models; Teaching Styles
IDENTIFIERS *Australia (Western Australia); Outstanding Teachers; Science Education Research

ABSTRACT

The Exemplary Practice in Science and Mathematics Education (EPSME) project involved outstanding teachers of science or mathematics from Western Australia. The project's goal was to identify effective practices of exemplary teachers for the purpose of developing programs for improving practices in science classrooms. Thirteen science teachers and 13 mathematics teachers from grades one to 12 were selected and participated in the study. This paper describes examples of effective and less effective teaching strategies for two teachers of the sixth grade and two high school science teachers. An analysis of the observed teaching behaviors is presented. Problems associated with inadequate content knowledge are identified. Recommendations are offered and the need for providing science training specialists in the primary schools is supported. (ML)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED281741

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

✓ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

EXEMPLARY PRACTICE IN SCIENCE CLASSROOMS

KENNETH TOBIN

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Kenneth Tobin

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

SE047935

BEST COPY AVAILABLE

ABSTRACT

The Exemplary Practice in Science and Mathematics Education study involved 26 teachers identified by educators as "above average". This paper describes teaching practices of two of these teachers of students in grade 6 and two high school science teachers.

The results of the study highlighted the importance of teachers having adequate pedagogical and science content knowledge. The two grade 6 teachers implemented "hands-on" activities but experienced difficulties in developing science content. In each case the incidence of student off-task behavior increased throughout the lesson. Although each teacher demonstrated some effective teaching practices, a lack of science content knowledge precluded the activities from being effective in facilitating student learning.

The two high school teachers had strong content and pedagogical knowledge. One teacher involved students in learning chemistry through small group activities while the other assisted students to develop understandings in whole class interactive activities which incorporated teacher demonstrations.

EXEMPLARY PRACTICE IN SCIENCE CLASSROOMS

There is little doubt that the findings of research in science classrooms can be depressing at times. The literature is replete with studies that describe the shortcomings of science teaching and problems that students face when they endeavor to accomplish the goals of science curricula. This has been the case in high school science where higher cognitive level outcomes are typically sought by curriculum designers. For the past 8 years at least, research has indicated that when the curriculum is implemented students do not receive many opportunities to learn higher cognitive level outcomes and they do not achieve them at the level that science educators (at least) would like.

In a number of case studies conducted in the U.S.A., Stake and Easley (1978) found that teachers emphasized learning facts about science and provided students with few opportunities to develop the higher level thinking skills that most courses purported to develop. The courses were very textbook oriented and students tended to lack motivation to learn about applications of science to the world outside of the classroom. Tests and examinations were found to be powerful motivating forces in most of the observed classrooms. A similar trend was reported by Mitman, Mergendoller, Packer and Marchman (1984) in a study of 11 junior high science classes. Mitman et al. noted that few academic tasks required students to use higher cognitive level skills. The authors reported that assessment tasks having most weight assigned to them (e.g. tests) had low cognitive demands. This situation was exacerbated by a tendency for teachers to grade worksheets and laboratory reports for completion rather than for accuracy.

Parallel findings were reported by Tobin and Gallagher (in press) in an Australian study of 15 high school science teachers. Tobin and Gallagher reported that science teachers emphasized completion of academic work to the possible detriment of students' understanding of the content. Teachers' emphasis on "getting the work done" seemed to be associated with concerns

that students cover the content to perform well on tests and to succeed at the next educational level. Teachers felt a responsibility to cover the work in the assigned time and planned and implemented lessons with a focus on covering course content. In most of these cases instruction did not provide opportunities for students to acquire higher cognitive level outcomes and tests did not assess them.

In some classes where teachers endeavored to emphasize higher cognitive level outcomes, barriers to higher level learning were created. Gallagher and Tobin (in press) described an interaction between classroom management and the cognitive demands of academic work in high school science activities. When the cognitive demands of the work were high, students demonstrated task avoidance behaviors that taxed the teacher's managerial effectiveness. In low ability classes teachers were able to retain control by changing activities so that students could engage without risk of failure. The cognitive demands of the academic work were reduced and students were content to engage. In one high ability class, students returned to a higher cognitive level task after a period of restlessness in which most of the class was off-task. These examples suggest that students engage in task avoidance behaviors when the cognitive demands of the academic work are high for sustained periods of time.

Penick and Yager (1983) deplored the spate of ethnographic studies and case studies that highlighted the plight of science education. They argued that case studies of excellence offered the promise of identifying aspects of science programs that did work so that other "school programs could begin building on what was known to work" (p. 621). The philosophy of Penick and Yager stimulated a good deal of excitement in the U.S.A., and our group of researchers in Australia planned a similar research effort based on the premise that we could learn a good deal from the best science teachers. In some respects our philosophy was similar to that espoused by Penick and Yager. However, there was one fundamental difference. Our group was committed to intensive classroom observations of teachers who were nominated

and eventually invited to participate in the study.

The philosophy of our research team is encapsulated in the following extract from a planning document for the investigation which was known as the Exemplary Practice in Science and Mathematics Education (EPSME; Tobin and Fraser, 1986) study.

> Since this study will focus on exemplary practice in science and mathematics teaching, it should be possible to avoid the situation encountered in so much educational research in which a depressing set of outcomes highlights the plight of science and mathematics education. The outcomes of this study will emphasize effective practices that can be used as models by other teachers. Documentation will be provided on characteristics of curricula and teachers that enable science and mathematics to be successfully taught in contexts that are pertinent to education in Western Australia. If the study is complemented with an effective dissemination process and appropriate in-service programmes, EPSME should lead to improved mathematics and science teaching in Western Australia. Accordingly, EPSME is seen as an important component of ongoing research on improving the quality of mathematics and science teaching.

The EPSME study involved a research team of 13 science and mathematics educators from Western Australia, and 26 teachers in schools in the metropolitan area of Perth, Western Australia. The teachers involved in the study were identified through a nomination process. Key educators in Western Australia, including teachers, State Education Department personnel, and university faculty were asked to nominate outstanding teachers of science or mathematics. Since the nominations were given orally, there was an opportunity to find out why they were considered outstanding. Not surprisingly, there was some resistance on the part of those approached to

nominate anyone as outstanding or exemplary. Consequently, we were required to alter our request for an outstanding teacher to a request for an "above-average" teacher. There was more comfort with this request, names were forthcoming, and lists of nominees were drawn up. Teachers who were nominated more frequently than others were invited to participate in the study.

There were some constraints imposed on selection. Each of our research team had other duties to attend to and stipulated that participants should be from schools within reasonable distance of their homes or workplace. In one instance a school principal refused to allow a physics teacher to be involved in the study, and a mathematics teacher was "too embarrassed to even talk about being involved". In all other cases the teachers who were approached and invited to participate in the study readily agreed to the request.

Eleven teams were formed to conduct case studies on specific teachers involved in the study. Each team consisted of one or two researchers, although some researchers were involved in more than one team. The teams focused on specific teachers in specific contexts. For example, different teams examined physics, chemistry, biology and general science in the high school. At primary school level two teams examined science taught in grades six and seven, and grades three and five respectively. The number of teachers involved in each of the case studies ranged from one to seven, and two of the science teachers were involved in more than one case study. Thirteen science teachers and 13 mathematics teachers from grades 1 to 12 participated in the study.

An interpretive research methodology (Erickson, 1986) was used in the study. The data were primarily qualitative and were obtained by direct observation of teaching by participant observers. The data that were collected consisted of observations of teaching for at least eight lessons, interviews with the teacher and students, and examination of curriculum materials, tests, and student work. Written tests and questionnaires were

also administered in many of the case studies. Interpretation of data occurred at the individual level, within teams, and at the entire research group level. Throughout the study, team meetings were held to facilitate discussion of administrative matters and substantive issues related to interpretation.

Our goal was to identify effective practices of exemplary teachers in an endeavor to develop programs for improving practice in science classrooms. The results indicated that exemplary teachers are strong in some, but not all areas. This finding, which has a ring of common sense to it, raises questions about programs such as the Search for Excellence which has relied on written documentation of the intended and implemented curriculum, questionnaires, and testimonial to a greater extent than direct observation. The salient lesson to be learned is that judgements about teacher performance need to be based on a substantial data base rather than casual observation and hearsay. In many cases, perhaps nearly all, there are significant differences in the intended and the implemented curricula.

PURPOSE

This paper describes examples of effective and less effective teaching strategies for four teachers observed during the EPSME study. The final section of the paper discusses the implications of these results for improving the quality of science teaching.

RESULTS

Primary Science Teaching

The first example concerns Richard, a teacher of a primary grade six class. Richard made an effort to model enthusiasm for participating in science, wondering about science, and applying science to the world outside of the classroom. He regularly used motivating techniques to involve students in science activities in an imaginative way as well as in a substantive way. For example, when students were given their record sheet prior to a materials centered activity, Richard asked them to write their

names on top of the sheet. At the top of the mimeographed sheet was the title Professor _____. He asked them to imagine what it would be like to be a Professor. Students clearly enjoyed the introduction to the activity and had a positive mindset prior to commencing work.

At the beginning of the activity, Richard discussed the properties of water. It was raining at the time and he told the class that this was why they were doing this activity rather than the solar energy activity that had been scheduled. Throughout the lesson he consciously manoevered from "classroom science" to "outside of the classroom science" in a skillful manner.

During the activity, Richard monitored student learning and provided assistance as required. As he moved around the classroom he participated in the activity and demonstrated interest in the results that students obtained. Richard was modeling the behaviors he expected students to exhibit. He did this in the general sense of being polite and friendly and in the specific science sense of inquiring and working with students on their activities in an enthusiastic manner.

One major problem emerged during the lesson. Students began to take advantage of the relaxed atmosphere, and as the lesson progressed the amount of off-task behavior increased. Students began to mess about with eye droppers, coins, and detergent in "non-scientific" ways. Although the teacher endeavored to bring the students under control he was unsuccessful, and many students were off-task for more than one-third of the one-hour lesson. While students were off-task they interfered with learning opportunities of others.

In terms of instruction, Richard adopted the plan of engaging learners in a whole class interactive mode when an investigation was planned and explained, and when the results were interpreted. Whole class interactive activities were characterised by extensive involvement of several boys in the class. These "target" students were eager to respond to teacher questions, routinely raised their hands following a teacher question, and

occasionally called out a response without waiting to be called to respond. The pattern that was evident in Richard's class was almost identical to that which has been described in studies of high school science and mathematics classes (e.g. Gallagher, 1985; Tobin & Gallagher, in press).

Two problems emerged regarding Richard's teaching practices. In small group activities classroom management was problematic, and during whole class activities, interactions were dominated by a few target students. Improvements in these two areas could result in enhanced learning opportunities for students.

Graham, was a primary school teacher of students in grade seven. He was nominated for the study by several Education Department personnel, teachers, and science educators on the basis of his interest in science education and his active endeavors to promote materials centered science programs in the State. When he taught science, Graham was clearly a materials centered science advocate. However, as was the case with Richard, he had severe management problems during his lessons. Unlike Richard, he did not commence lessons by attending to student motivation, and within a short period of time students were involved in using materials to solve a problem. For example, in one lesson students were given a handful of drinking straws and a number of pins and were instructed to make a tower that was self supporting. Classroom management was problematic from the outset of this lesson and became more so as the lesson progressed. Students were organized into groups, but generally speaking, the groups were unproductive. Although the teacher monitored student work, an increasing number of students were off-task throughout the lesson.

Graham had other problems as well. Although he monitored student behavior, he did not monitor student thinking. He moved about the room attending to administrative matters, leaving students to construct their own knowledge without teacher cues or feedback. In some groups certain individuals monopolized the materials and prevented others from manipulating

the pins and straws. In other groups there was division of labor as the "architects" supervised the "workers". At the end of the data collecting activity Graham asked students to pack away the equipment. There was no time allowed for discussion of results.

High School Science Teaching

Garth and Don were teachers who were exemplary in most respects. Each taught high school chemistry, but at different schools. Garth taught at a comprehensive co-educational high school and Don taught at a girls Private high school.

Garth used groups for most of the time during his lessons. Although he was teaching chemistry to students in grades 11 and 12 he involved students in constructing their own knowledge in a variety of ways during the study. For example, following a lively discussion on the reaction between hydrochloric acid and magnesium, his grade 11 class was given the problem of calculating the number of moles of magnesium needed to produce 50 ml of hydrogen at STP. Having calculated an answer the class was expected to confirm the result experimentally. In order to do this they had to calibrate a burette to measure the volume of hydrogen. Once the activity started, Garth monitored student engagement and actively taught students without reducing the cognitive demands of the task. The students were working in groups, but there were no obvious examples of students copying work from one another. If a student had difficulties the teacher appeared on the scene and a private conversation ensued.

Of course there were examples of students dealing with their social agendas during group work. However, the teacher did not have to call the class to order, and noise levels were never excessive. Garth had established a routine of working with students in groups. If students appeared to be socializing, Garth was there before it became too much of a problem. It was apparent that the students knew what to do and what to expect during the lessons that were observed.

Garth had extensive knowledge about teaching and a strong background in

high school science. His knowledge was active in the sense that it could drive behavior during teaching. During science lessons Garth was relaxed and clearly able to think about instruction and how to better engage individuals in the class.

Don was a contrast to Garth. His teaching was mainly to the whole class and he perceived his role differently to Garth. Whereas Garth was an advocate of students constructing their own knowledge, Don perceived his role as presenting knowledge in a form that would enable students to make the necessary connections. Don's own academic background in chemistry was considerably stronger than Garth's, although each had a more-than-adequate background. During class Don used demonstrations effectively and passed around materials so that students could have first hand experience with the chemicals to which he was referring. He attended to the important aspect of relating chemistry to the world outside of the classroom in an effective manner. In fact his general knowledge was impressive as he was able to take current events in the mining industry and interrelate economic and environmental issues with the chemistry that was being discussed. By so doing, he used demonstration, lecture and whole class interactions. However, he did not appear to have target students and girls were systematically involved in the lesson. During a lesson on extraction of aluminum, students appeared comfortable asking the teacher questions and responding to the many teacher questions.

DISCUSSION

The examples involving Richard, Graham, Garth and Don are illustrative of the findings of the EPSME study. Some teachers were very good indeed, some were average, and some had numerous difficulties. Across the 26 teachers involved in the study we learned a lot about teaching. Just as we learned about motivation from Richard, group work and cognitive demand from Garth, and building science concepts from Don, we were able to learn about many other exciting teaching routines from other teachers. Consequently,

the study was worthwhile in identifying some exemplary practices and assisting us to understand why some things would not work in particular contexts. What was not clear from the study was what we would do with the information now that we had it.

An examination of the relative content strengths and weaknesses of the four teachers involved in this study highlights some salient points. Don and Garth had degrees in science and were able to use their knowledge to stimulate overt learner engagement on higher cognitive level objectives. Students in their classes were involved in thinking about science content in an overt way. This was not the case to the same extent in either of the primary teachers' classes. Of course some of the differences could be explained in terms of the relative ages of the students involved. Perhaps older students could be expected to engage in higher cognitive level tasks more often and for longer periods than younger students. Although this might be the case, my own interpretation is that the two high school teachers facilitated overt student engagement through the strategies that they used. In Garth's case he was able to use questions directed to individuals to promote thinking about content in materials centered environments. This was possible because he had a firm grasp of the content that he wanted to teach and he knew how to sustain student engagement. His monitoring was effective because he was in the right place at the right time and he had the content knowledge to maintain the momentum of the lesson He could ask students what they were thinking and could provide feedback on the substance of their thoughts.

Although Don did not use small groups in the same way as Garth, he was able to keep students engaged because of his skills in whole class interactive activities. He used demonstrations to provide concrete referents for student thinking and he involved students in a systematic manner in answering well-chosen questions. Because of his extensive knowledge about the subject that he was teaching he was able to introduce the content in an appropriate manner and assist student to link the

concepts within lessons and from one lesson to the next. Don's obvious enthusiasm for chemistry teaching and his tendency to use illustrative examples from real life, provided students with a model of how science ought to be presented and learned.

The two primary teachers provided a marked contrast to the two secondary teachers and to one another. Each of these teachers was certified to teach primary grades and was not a specialist science teacher. Their preparation as science teachers was based on professional courses in their education degrees and graduate work in science education. The focus of all science related courses they had taken was on teaching science. The emphasis was on curriculum resources and types of activities that were appropriate for teaching and learning of science. In addition, Don and Richard were enthusiastic science teachers with a conviction about the value of primary students learning science in a "hands-on" manner.

My interpretation of the lessons that I saw is that neither of these teachers possessed sufficient knowledge of science to successfully implement activities of this type. They knew how to arrange students in groups, how to get the activities started, but they were unable to assist students to develop science content from the activities. Richard made attempts to focus student thinking on concepts associated with the properties of water. There was no doubt that he knew how to monitor student engagement and how to probe student thinking. However, he could not ask the crucial questions to focus student thinking on what was to be learned. In fact, there was no evidence that Richard knew what students were supposed to learn from the activity. The data collecting part of the lesson became an end in itself, and there were no links forged between the activity and the subsequent discussion of properties of water in the post-lab discussion. Failure to focus on content development during the activity is a possible reason for the increasing incidence of off-task behavior during the activity.

Graham appeared to have even less content knowledge about structures.

The activity was a favorite of Graham's and he had taught sequences of lessons involving structures on many occasions in the past. Unlike Richard, he did not endeavor to monitor student thinking during the activity on structures. His concern was with classroom management. As a consequence, students focused their attention on construction and competing with other groups in the class. During the lesson they were left to their own resources to discuss observations that may have been relevant to the content they were to learn. Undoubtedly each student in the class learned something about construction, but it was apparent that the potential of the learning environment that had been established was not realized because of the relative inactivity of the teacher. His failure to attend to the cognitive needs of students was reflected in their inappropriate behavior throughout the lesson.

The two sets of science teachers provided an interesting contrast which has helped the EPSME team to focus on the importance of teachers having adequate pedagogical and content knowledge. In this study, each of the four teachers had adequate pedagogical knowledge, however, only the two high school teachers had sufficient knowledge of science. The lack of necessary content knowledge has important implications for assisting the two primary teachers to improve their teaching.

How can a deficiency in content knowledge be redressed? Planning is an obvious way to overcome the problem. But Richard and Graham are required to teach subjects such as mathematics, social studies, English, art, and physical education as well as science. Presumably, they are limited in their knowledge of these subjects too. The task of building a sufficient knowledge base and maintaining the currency of that knowledge base seems to be too large for most primary school teachers. Since we were looking at two of the better primary school teachers in this study, my conclusion is that the task of upgrading the science knowledge of all primary teachers to a satisfactory level is just too great to contemplate. Consequently, serious consideration should be given to training specialist teachers to implement

the science curriculum in primary schools.

When we began the EPSME study we expected to identify exemplary practices which would serve as models for teachers wanting to improve their teaching. It is now apparent to us that our model for improving teaching was probably too simplistic. There is no doubt that videotapes of any of these teachers in action could provide a context in which a change process could begin. Critical instances from a videotaped lesson could be identified and used as a basis for discussion and stimulating reflection on a teacher's personal teaching style. According to Schon (1983, 1985), reflective practices can initiate an intention to change, which appears to be an essential ingredient for improvement of teaching.

If improvements are to be sustained, we should realize that teachers will probably need to identify the area in which change is needed and believe that the changes will be worth the effort. Having made the initial commitment, teachers need to acquire the knowledge needed to implement the change and put the changed practices into effect. Unless they are successful or receive encouraging feedback and support, teachers might opt to discontinue the changed teaching practices after an initial trial.

CONCLUSIONS

The EPSME study provided a substantial knowledge base concerning effective teaching practices in science and mathematics classes. One challenging outcome of the study is that no matter how good a teacher might be there will inevitably be some area in which they can improve. However, the best way to effect change is not clear and it is unlikely that there will be only one best way. The challenge that faces our research group in the wake of EPSME is to identify how teachers can construct knowledge about science content and teaching so that their teaching performance improves. In order to address this task and to learn about the art and craft of teaching it will be necessary to further explore classrooms of exemplary and non-exemplary teachers. There might be something to the old maxim that

teachers are born not made. More likely the statement rests on the fact that teaching is very hard to change because knowledge of teaching develops over a long period of time and the active knowledge that drives behavior is difficult to change and to construct. As a consequence, teachers find it difficult to improve. If classroom researchers are to seriously address the issue of improving science teaching and learning we must learn more about the role of different knowledge forms in teaching.

REFERENCES

Erickson, F. (1986). Qualitative methods in research on teaching. In Wittrock, M.C. (ed.) Handbook of research on teaching (3rd Edition). NY: Macmillan Publishing Co.

Gallagher, J.J. (1985). Secondary school science (Interim Report). East Lansing: Michigan State University, Institute for Research on Teaching.

Gallagher, J.J. & Tobin, K. (in press). Teacher management and student engagement in high school science. Science Education.

Mitman, A.L., Mergandoller, J.R., Packer, M.J. & Marchman, V.A. (1984). Scientific literacy in seventh grade life science: A study of instructional process, task completion, student perceptions and learning outcomes. San Francisco, CA: Far West Laboratory for Educational Research and Development.

Penick, J.E. & Yager, R.E. (1983). The search for excellence in science education. Phi Delta Kappan, 621-623.

Schon, D. A. (1985). The design studio: An exploration of its traditions & potential. London: RIBA Publications Limited.

Schon, D. A. (1983). The reflective practitioner: How professionals think in action. New York: Basic Books, Inc.

Stake, R.E. & Easley, J.A. (1978). Case studies in science education (Vols 1 & 2). Urbana: Center for Instructional Research and Curriculum Evaluation and Committee on Culture and Cognition, University of Illinois at Urbana-Champagne.

Tobin, K. & Fraser, B. J. (1986). Exemplary practice in science and mathematics. Perth, Western Australia: Western Australian Institute of Technology.

Tobin & Gallagher (in press). Target students in the science classroom. Journal of Research in Science Teaching.